

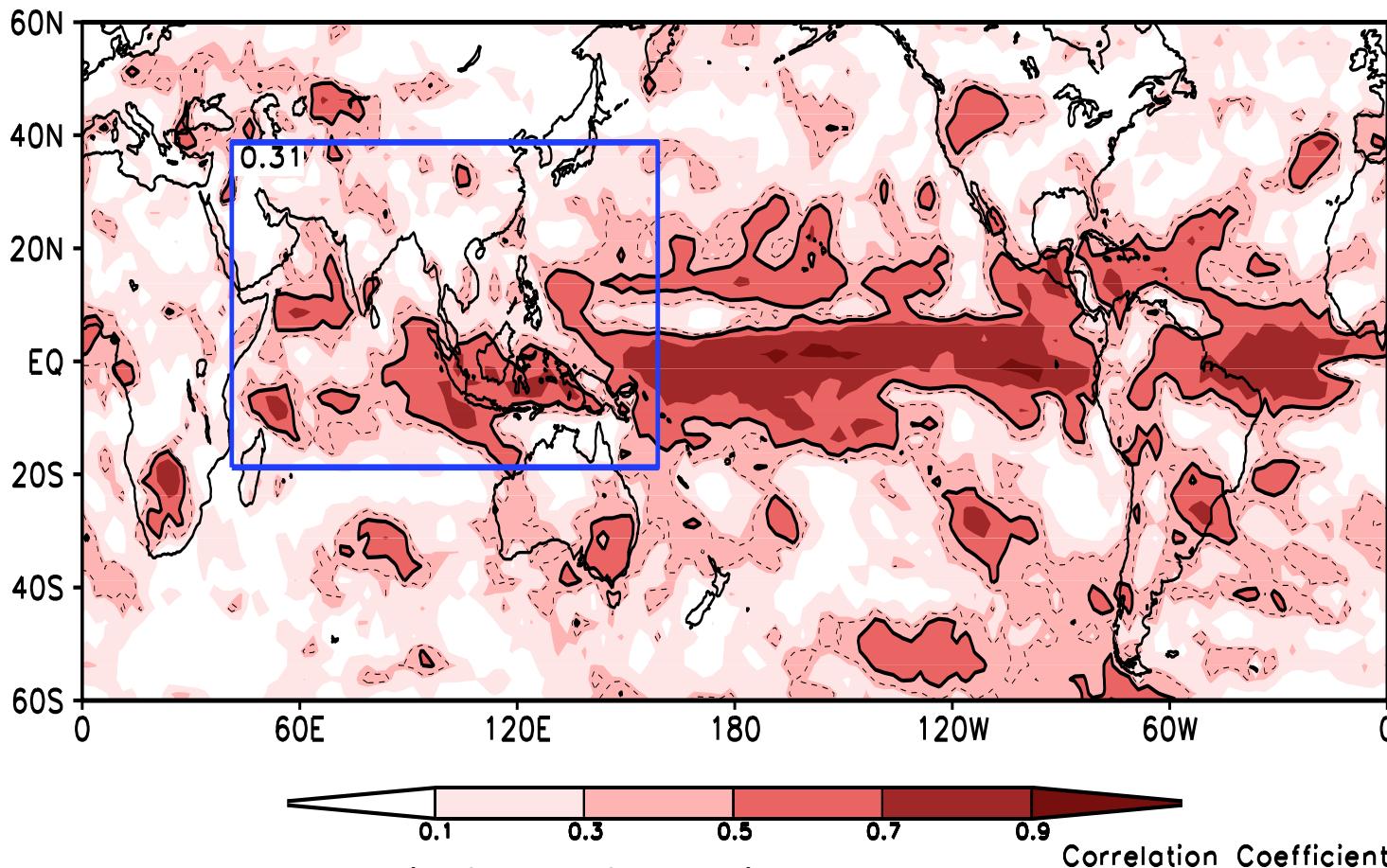
Asian Summer Monsoon Rainfall Predictability: An Predictable Mode Analysis

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Dynamical models' MME prediction skill

Temporal correlation skill for JJA rainfall (1979-2010)



NCEP CFS version 2 (Saha et al. 2011),
ABOM POAMA version 2.4 (Hudson et al. 2011),
GFDL CM version 2.1 (Delworth et al. 2006), and
FRCGC SINTEX-F model (Luo et al. 2005).

Dashed contour: 0.35
(significance at 0.05);
solid contour: 0.5.

Blue box: AAM
region.

Averaged TCC
skill over the
AAM region is
0.31. Land skill

low.

An important long-standing issue

To what extent the Asian summer monsoon (ASM) rainfall is predictable?

We will use a predictable mode analysis (PMA) method to estimate the potential predictability of the ASM rainfall.

Predictable Mode Analysis (PMA)

An integral approach combining **empirical analysis, physical interpretation and hindcast exp..**

Empirical analysis detects most important modes of variability;

Physical interpretation establishes their physical basis and a **Physics-based-Empirical model**;

Retrospective predictions by empirical and dynamical models identify the “predictable” modes.

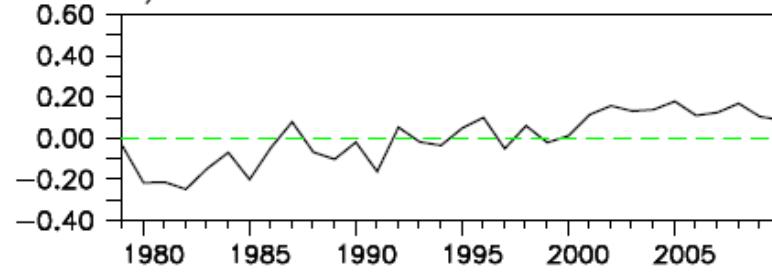
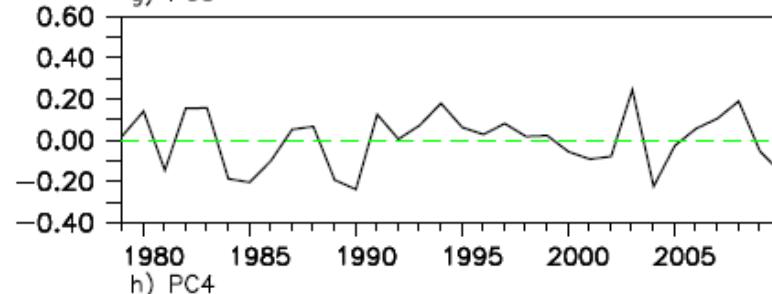
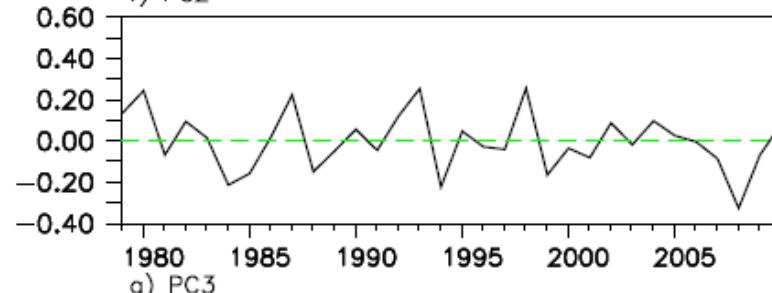
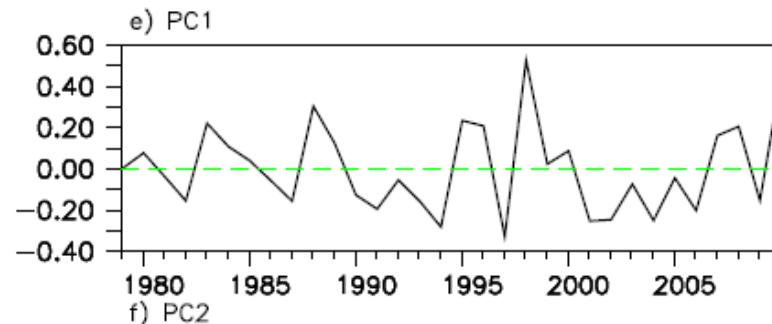
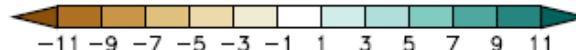
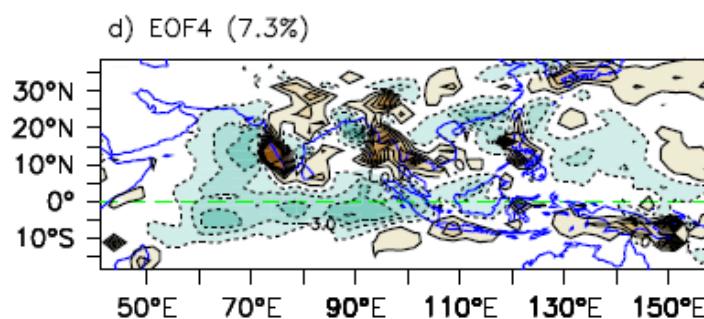
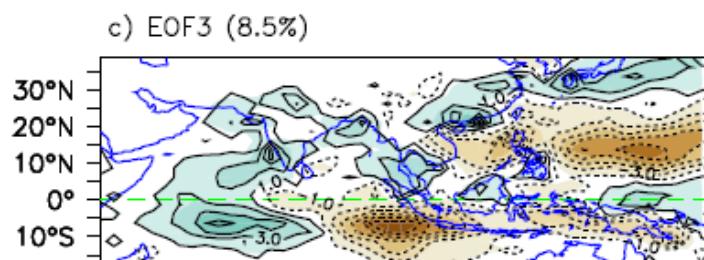
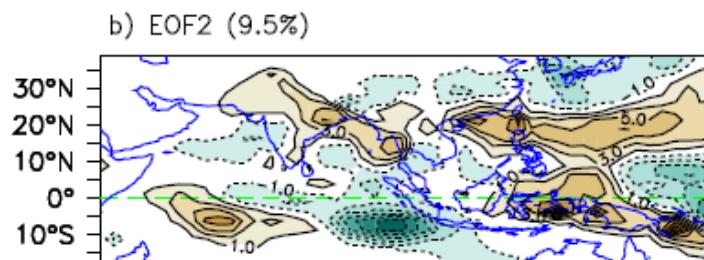
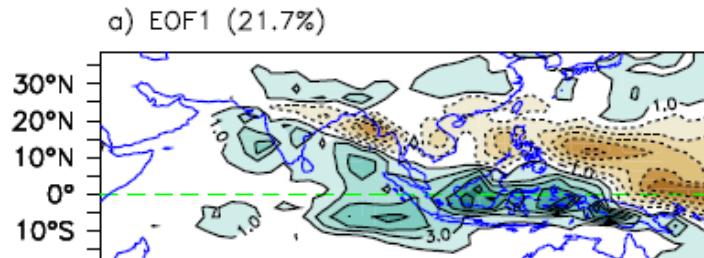
The **potential predictability** can then be estimated by the **fractional variance accounted for** by the “predictable” modes.

References: Wang et al. 2007, Lee et al. 2011; Lee et al. 2013

Outline

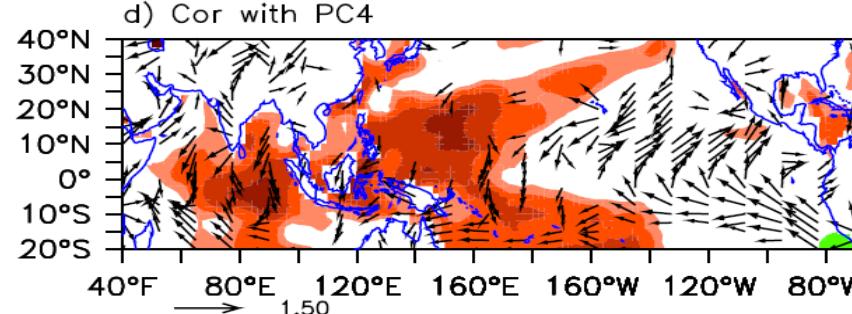
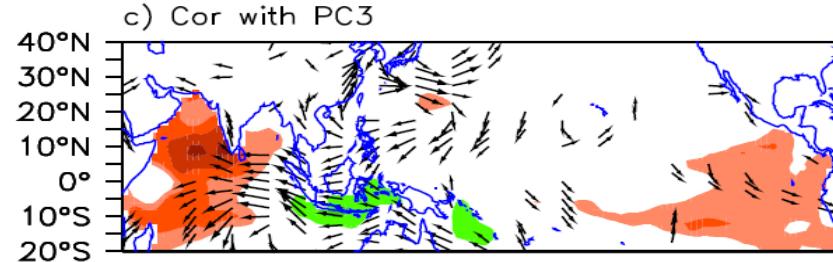
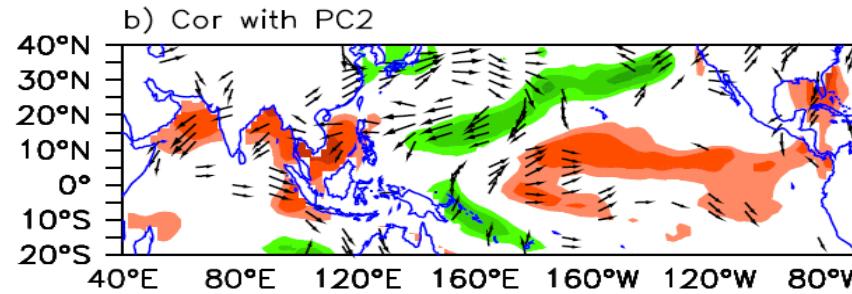
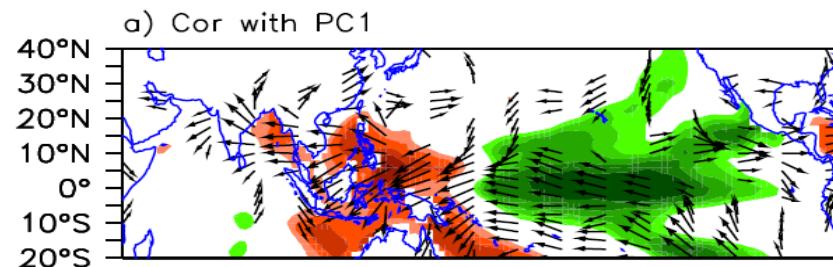
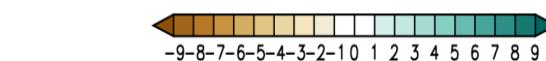
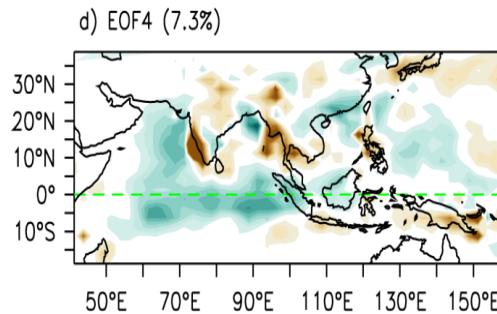
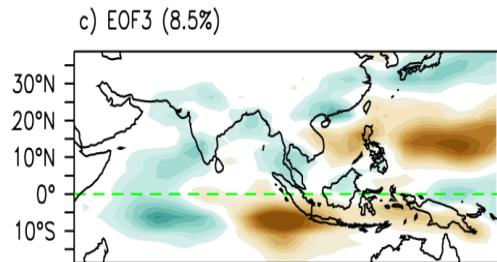
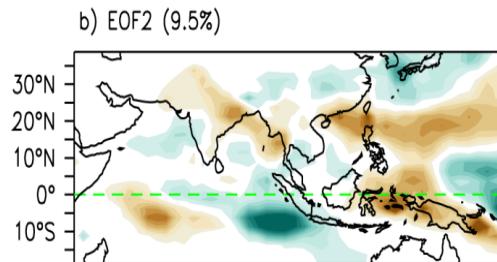
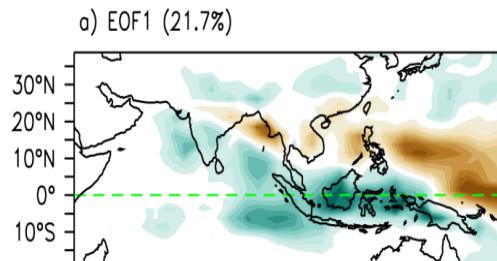
- Detection of Major modes
- Physical Interpretation
- Retrospective predictions
 - (physical-empirical model and dynamical models MME)
- Estimate the Predictability
- Hindcast skill after bias correction

Four leading EOF modes of JJA AAM Rainfall



47%

Interpretation of the major modes of variability



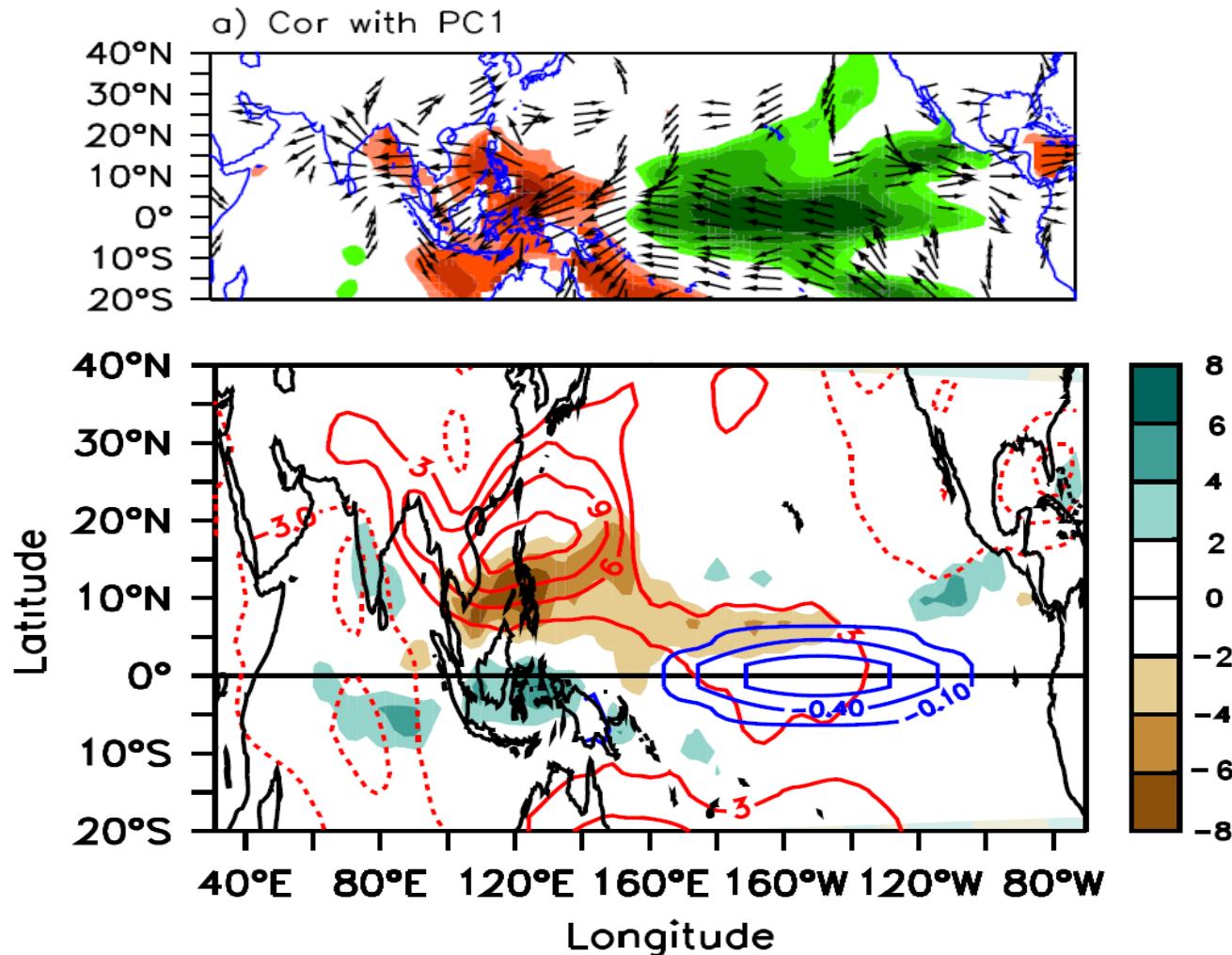
CP-ENSO
Developing

Indo-Pacific
A-O
coupling

IOD or IZM
R=0.77

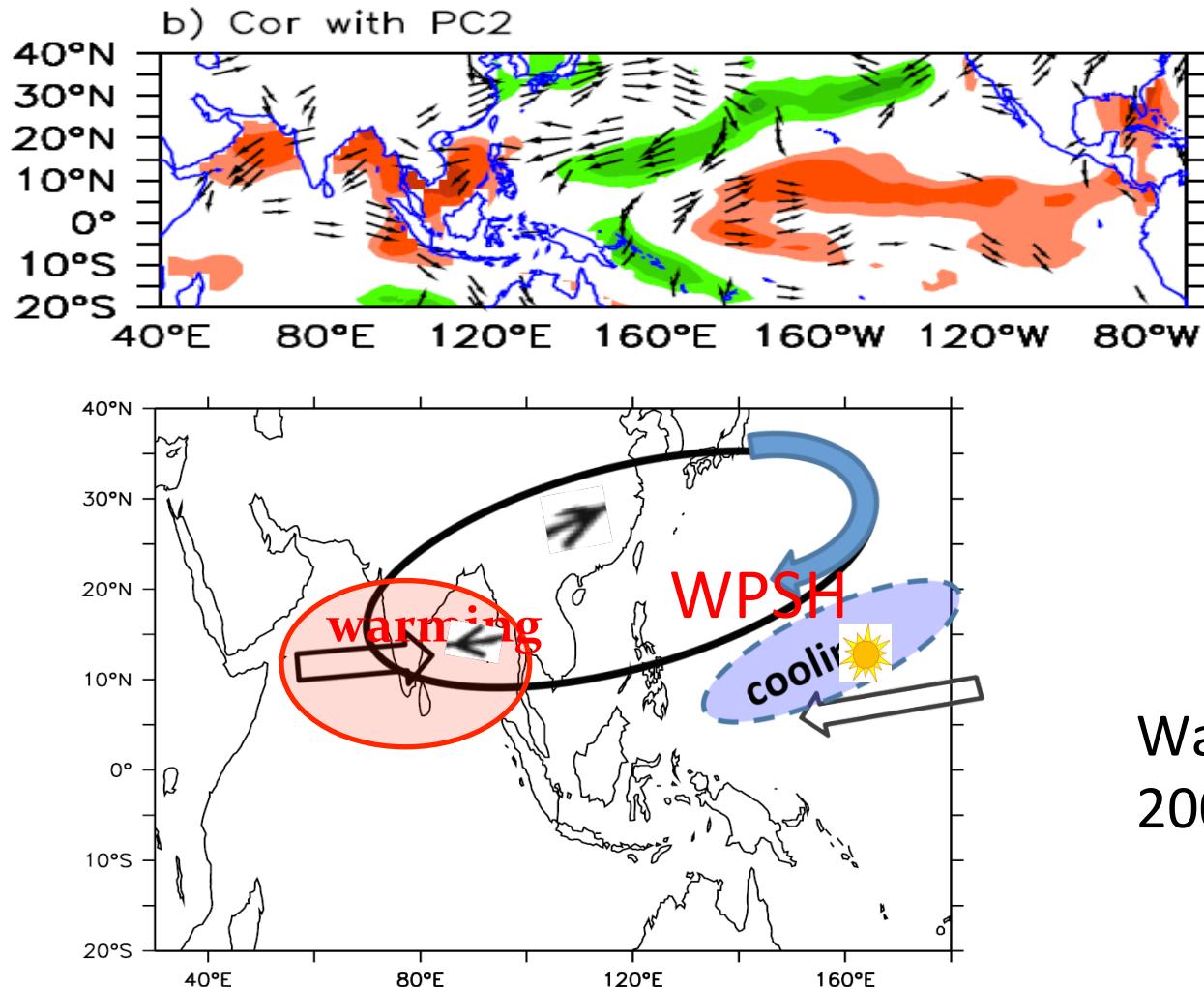
Warm
pool
warming

EOF1: Forced response to CP cooling



ECHAM ensemble experiments
Anomalies forced by ECP SST cooling

EOF 2: Indo-Pacific coupled Mode

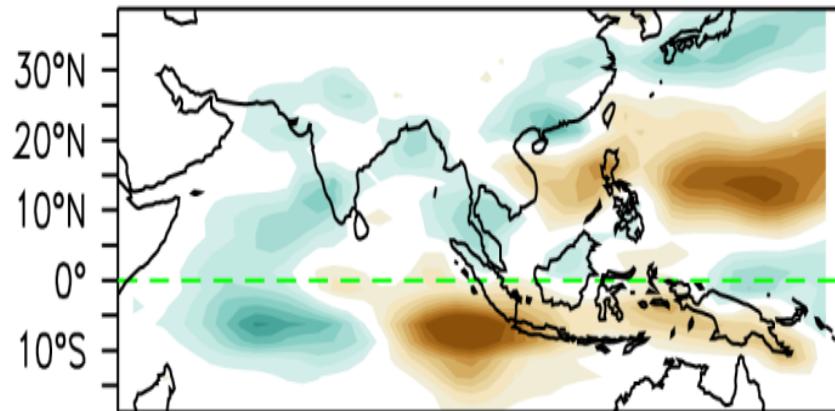


Wang et al.
2000, 2013

Positive A-O thermodynamic feedback between the WPSH and the Indo-Pacific warm pool ST dipole

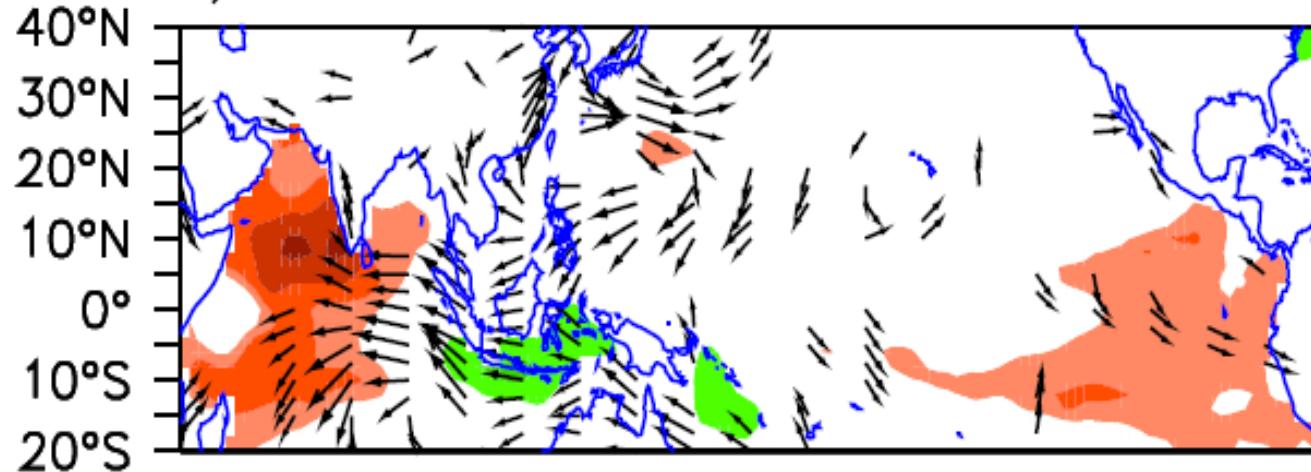
EOF 3: Indian Ocean Zonal mode or IOD

c) EOF3 (8.5%)



Saji et al. 1999,
Webster et al. 1999

c) Cor with PC3



Retrospective Prediction of AAM rainfall (1979-2012)

1. Physical-empirical model
2. Dynamical models' MME

Predictable Mode analysis: Forecast Models

Dynamical models or MME

$$R_TS(lon, lat, t) = \sum_{i=1}^N W_i(lon, lat) PC_i(t)$$

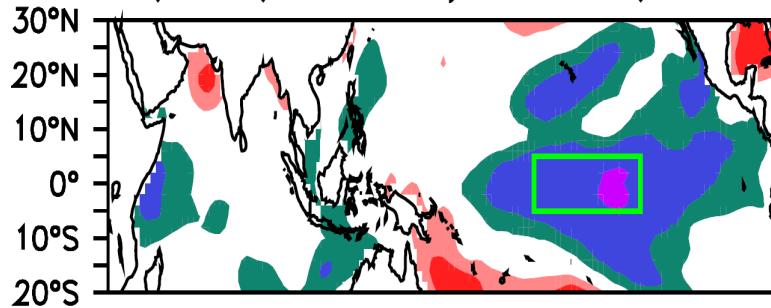
Physically based Statistical model

$$R_TS^N(lon, lat, t) = \sum_{i=1}^N W_i(lon, lat) PC_i^N(t)$$

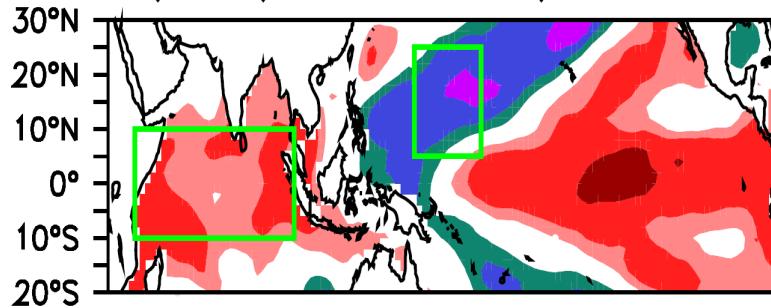
$$PC_i^N(t) = a_i Pred_i(t - \tau)$$

Physical-empirical predictors for 4 PCs

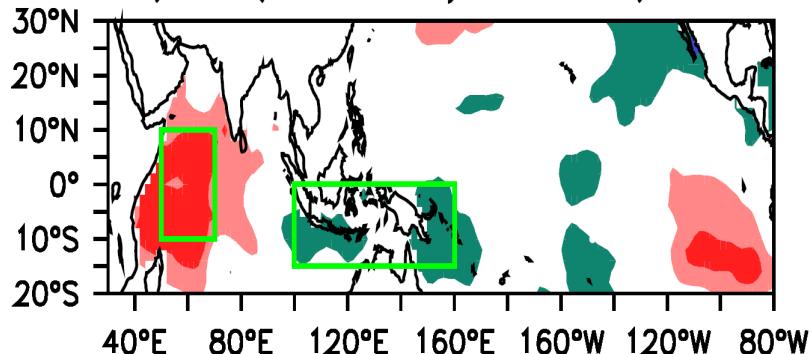
a) Cor (EOF1 & May–Mar SSTA)



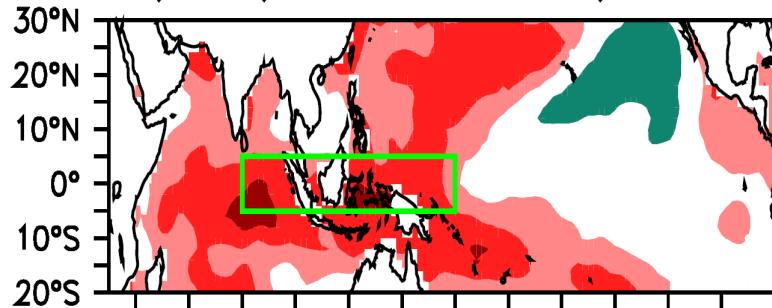
b) Cor (EOF2 & AM SSTA)



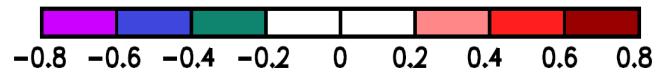
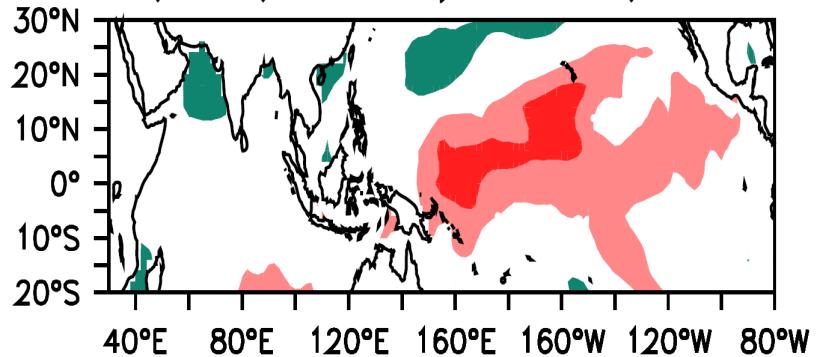
c) Cor (EOF3 & May–Mar SSTA)



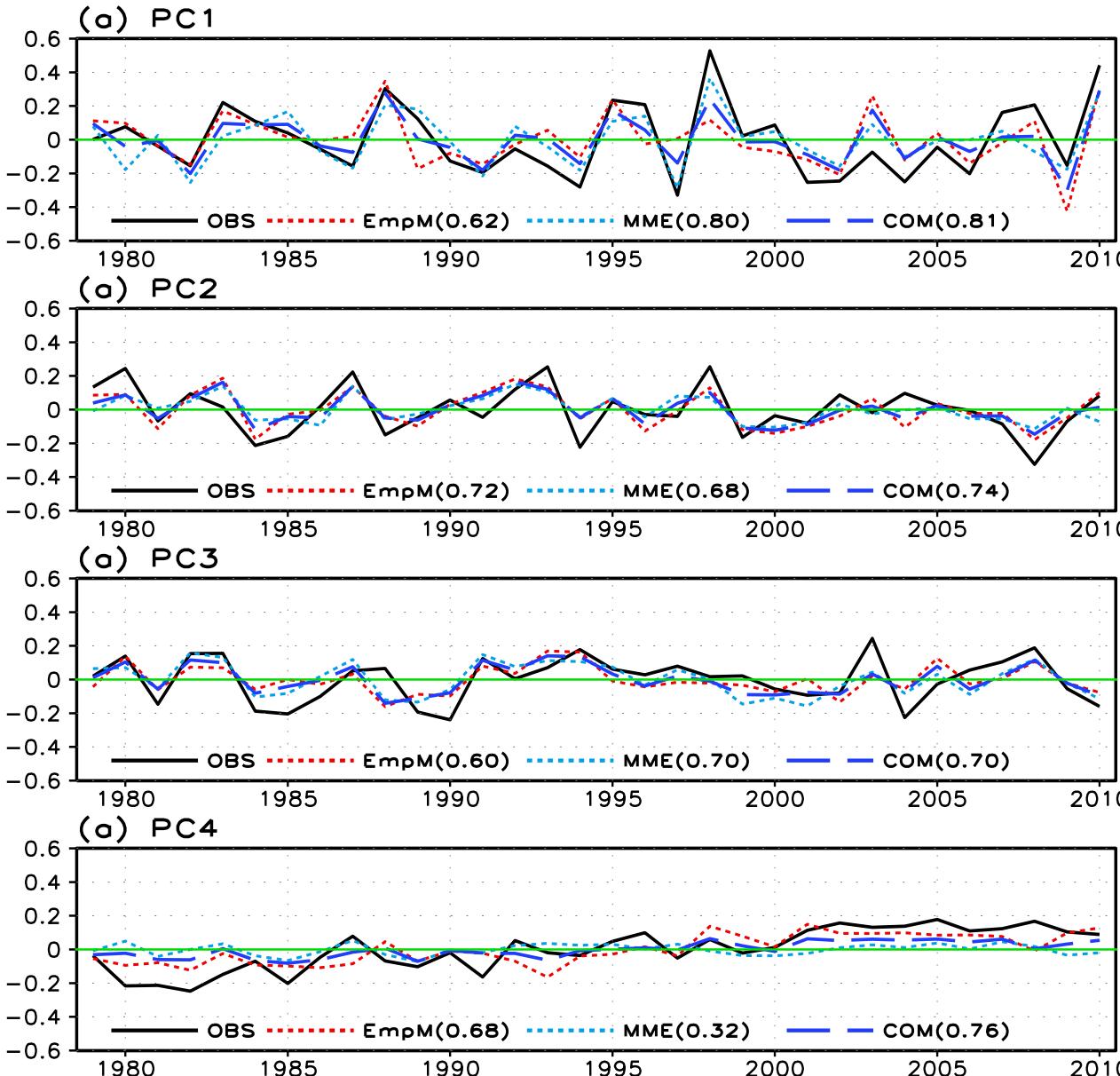
d) Cor (EOF4 & JFMAM SSTA)



e) Cor (NAOI & May–Mar SSTA)



Cross-validated Prediction skill for the four PCs



PE model
predicts PC2
and PC4 better

MME predicts
PC1 and PC3
better

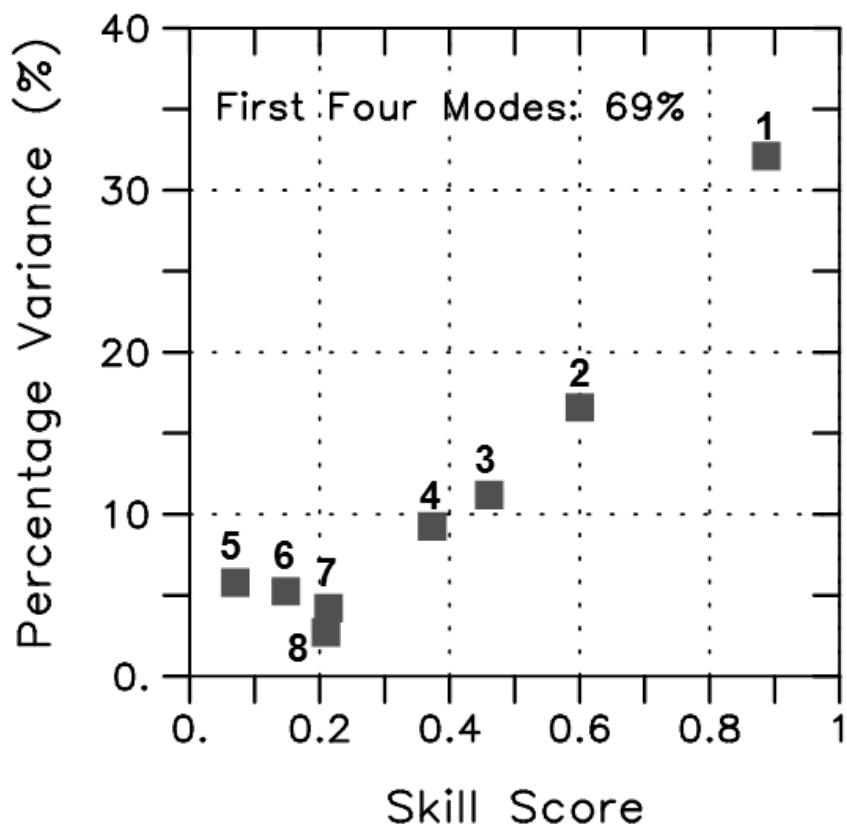
Combined
scheme
predicts all
four PCs well:
0.70-0.81

Estimation of potential predictability: Predictable mode analysis

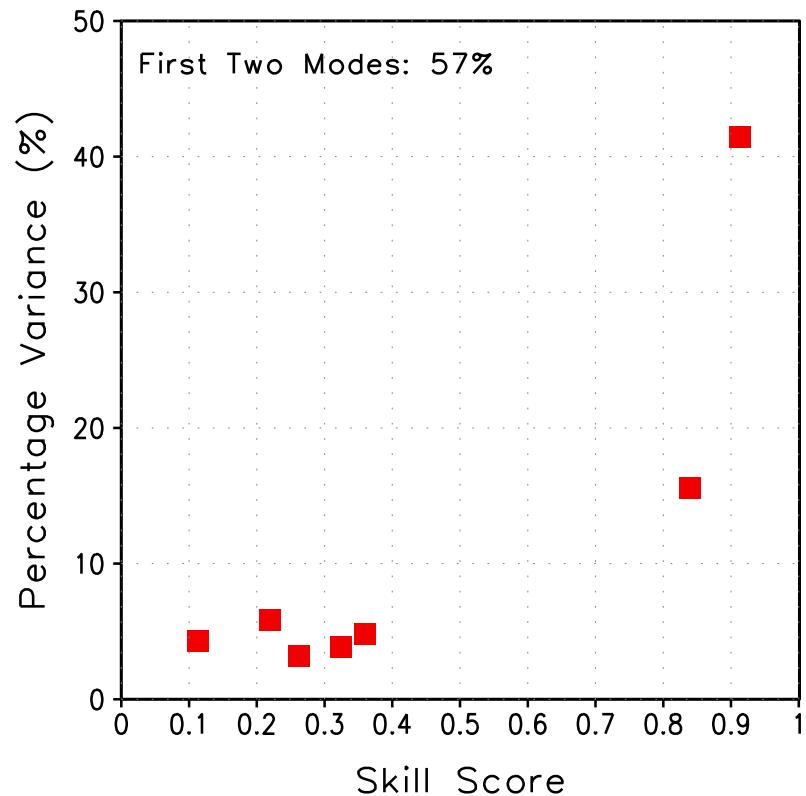
What are predictable modes?

Scatter Diagram of skill score and percentage variance for each EOF mode

JJA 200 hPa GH



Asian winter monsoon



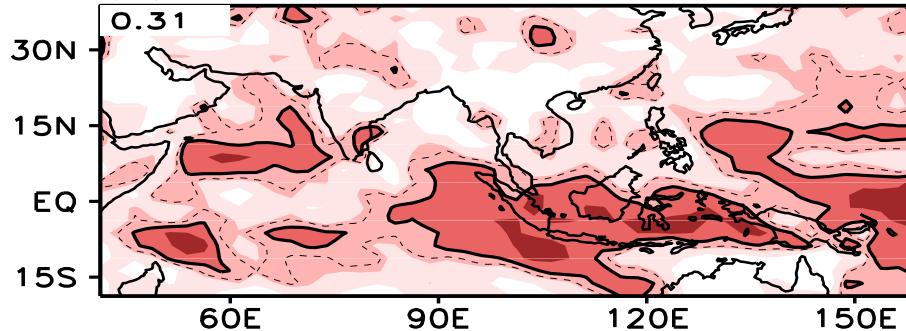
Skill Score: $\text{SQRT}(\text{PCC} * \text{TCC})$

TCC: Temporal correlation skill for PC time series for each mode

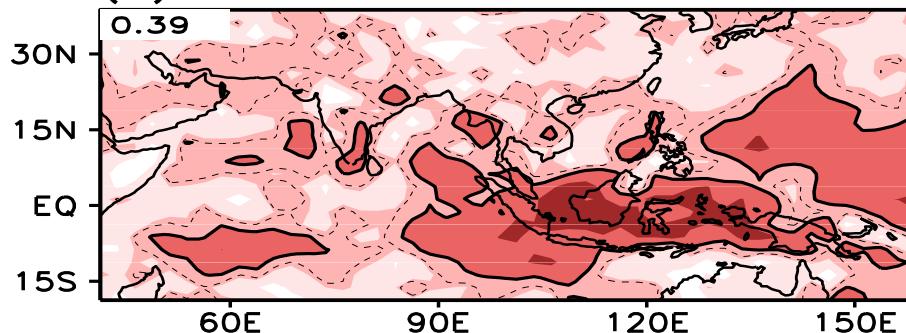
PCC: Pattern correlation skill for eigen vector for each mode

Dynamical model MME prediction:

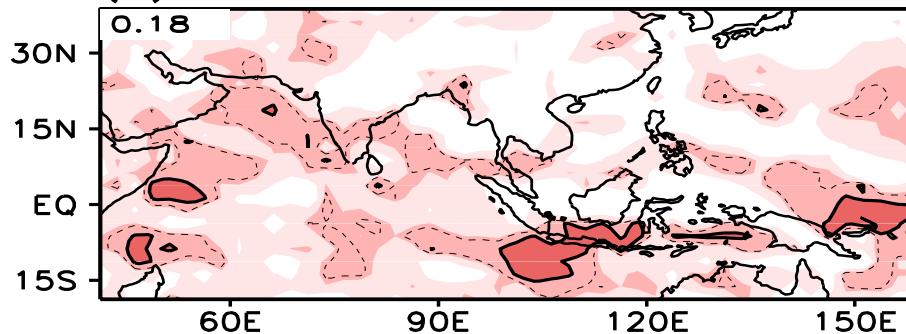
(a) MME with all modes



(b) MME with first four



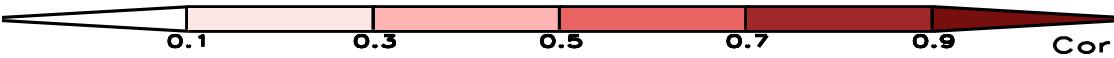
(c) MME with residual modes



MME, total (all modes):
0.31

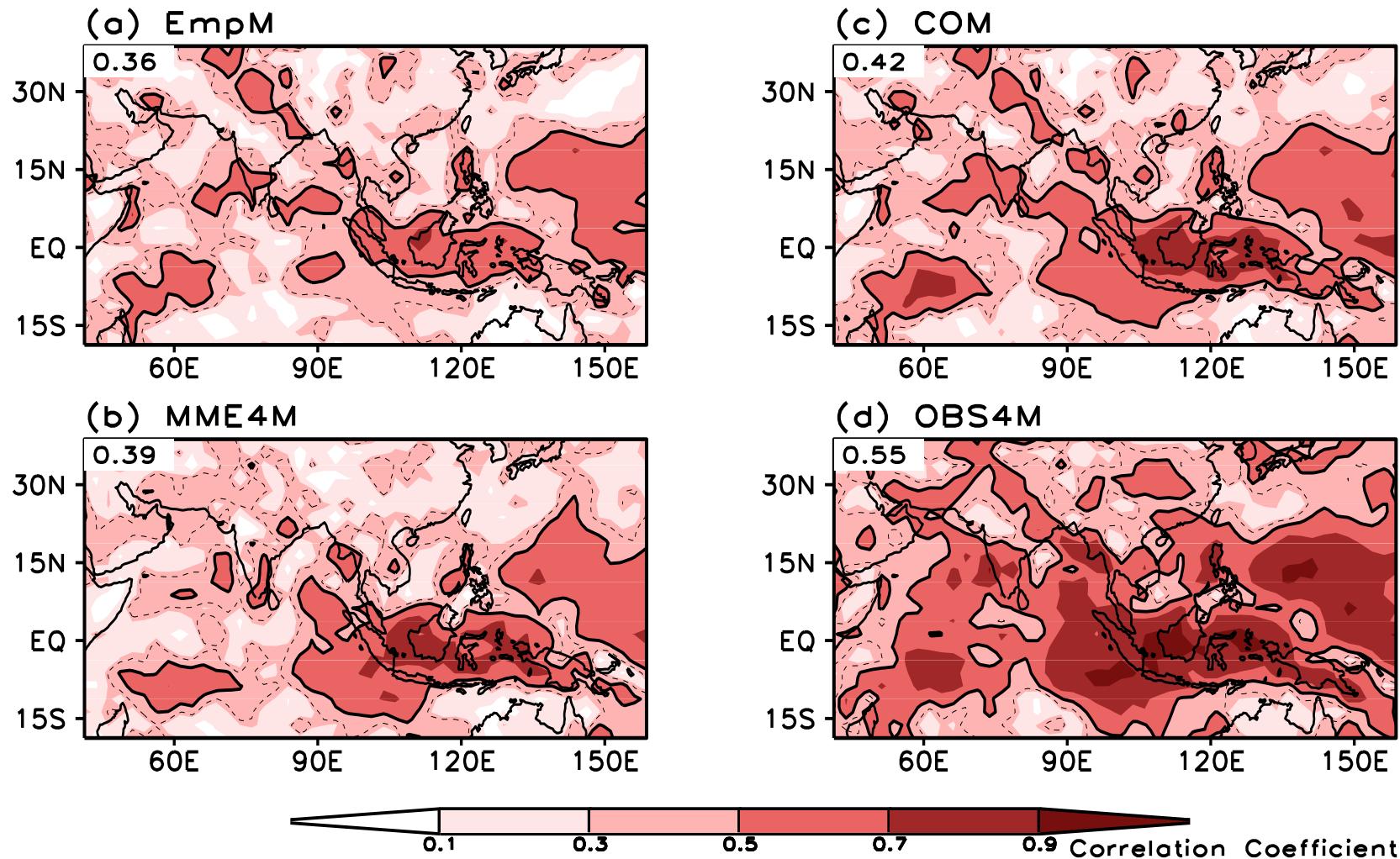
MME using only 4 modes : 0.39
but using observed EOF patterns

The residual modes has small contributions



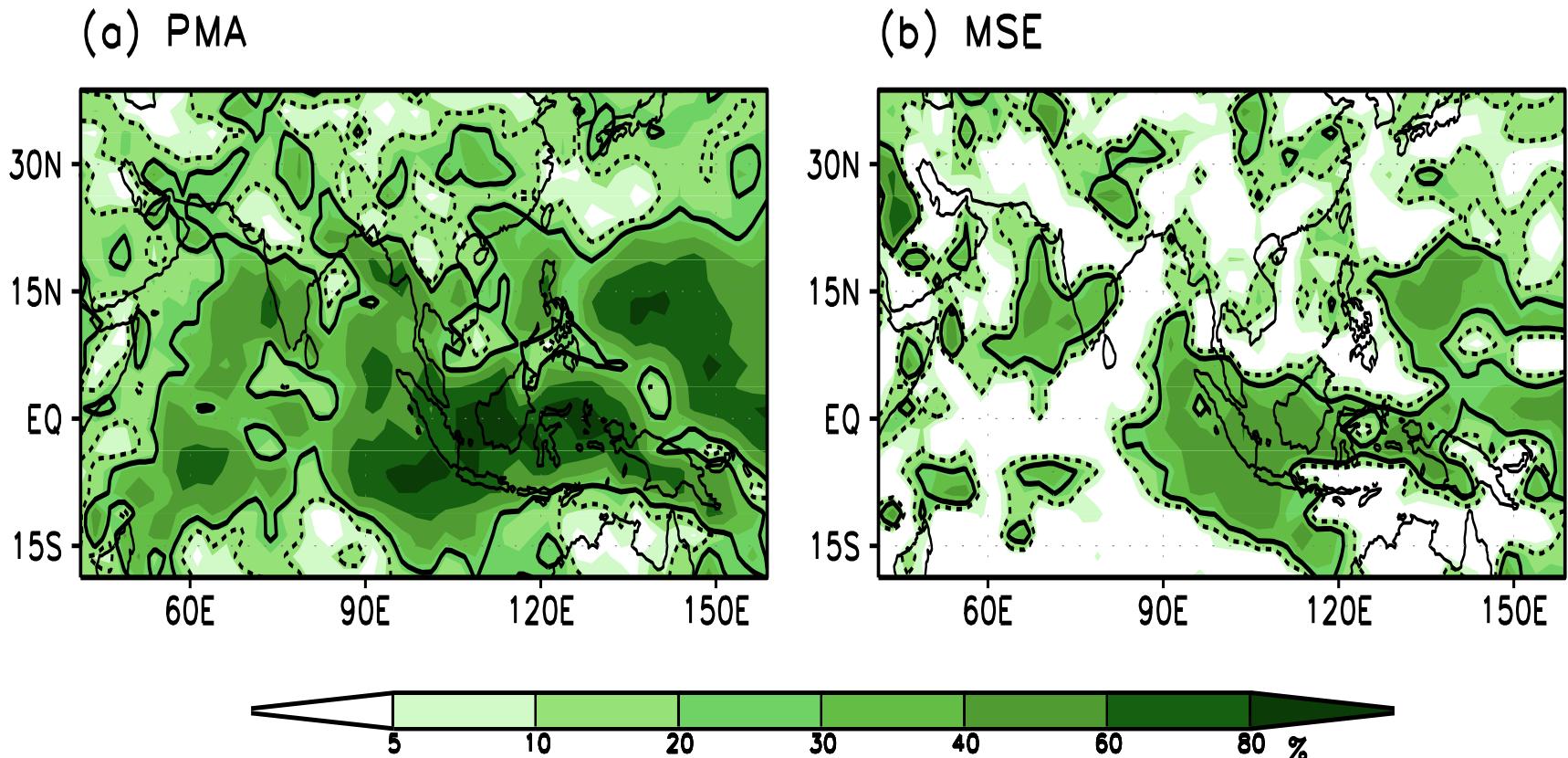
Correlation Coefficient

Potential predictability and Predictable Modes Forecast skill



The dashed contour: 0.35 (significance at 0.05); solid contour: 0.5. The averaged TCC skill over the AAM region is shown Skills over land improved significantly.

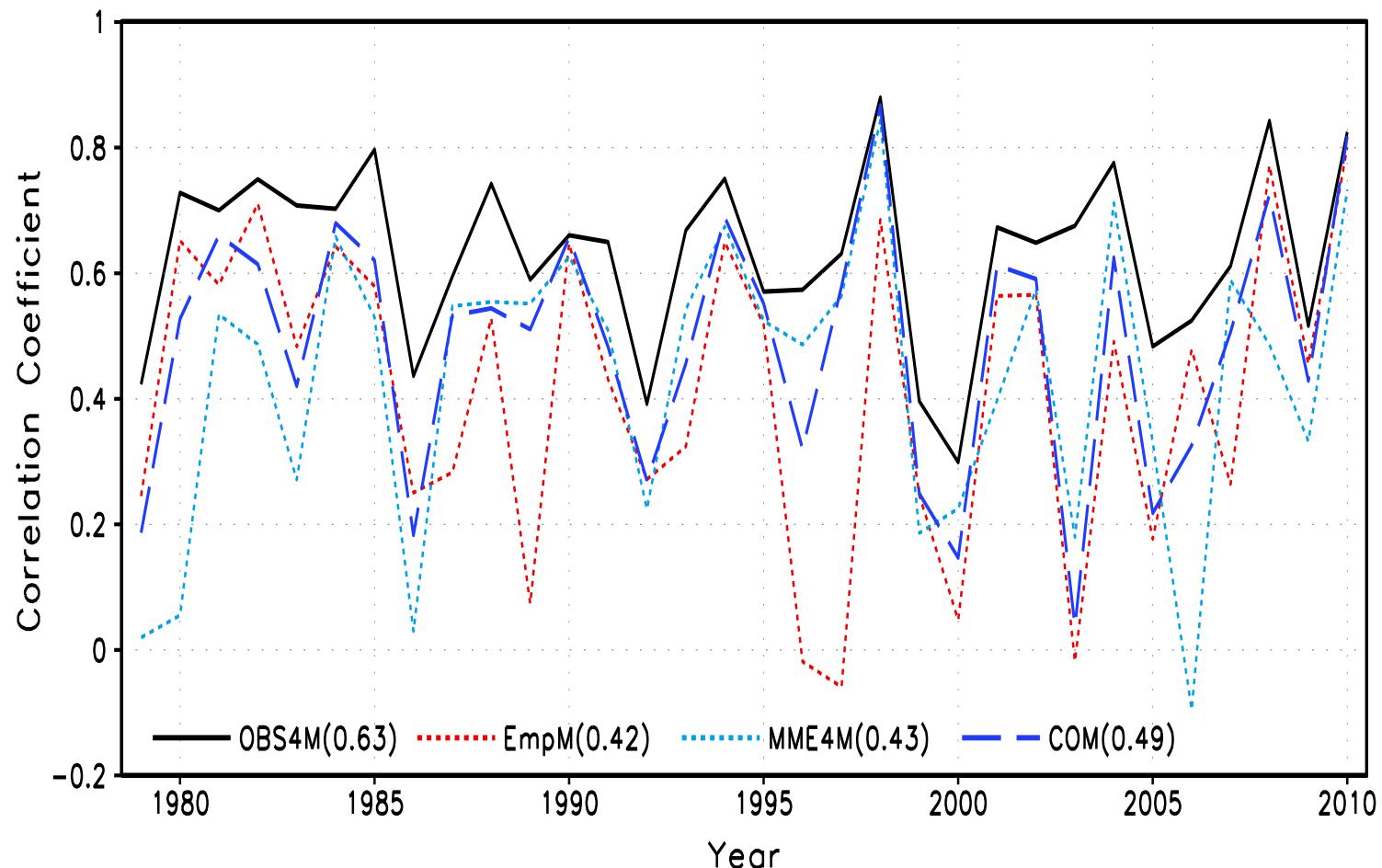
Potential predictability estimated by PMA and MSE



MSE: Mean Square Error method (Kumar et al. 2006): Perfect models, large ensembles are required. PMA method (Wang et al. 2007)

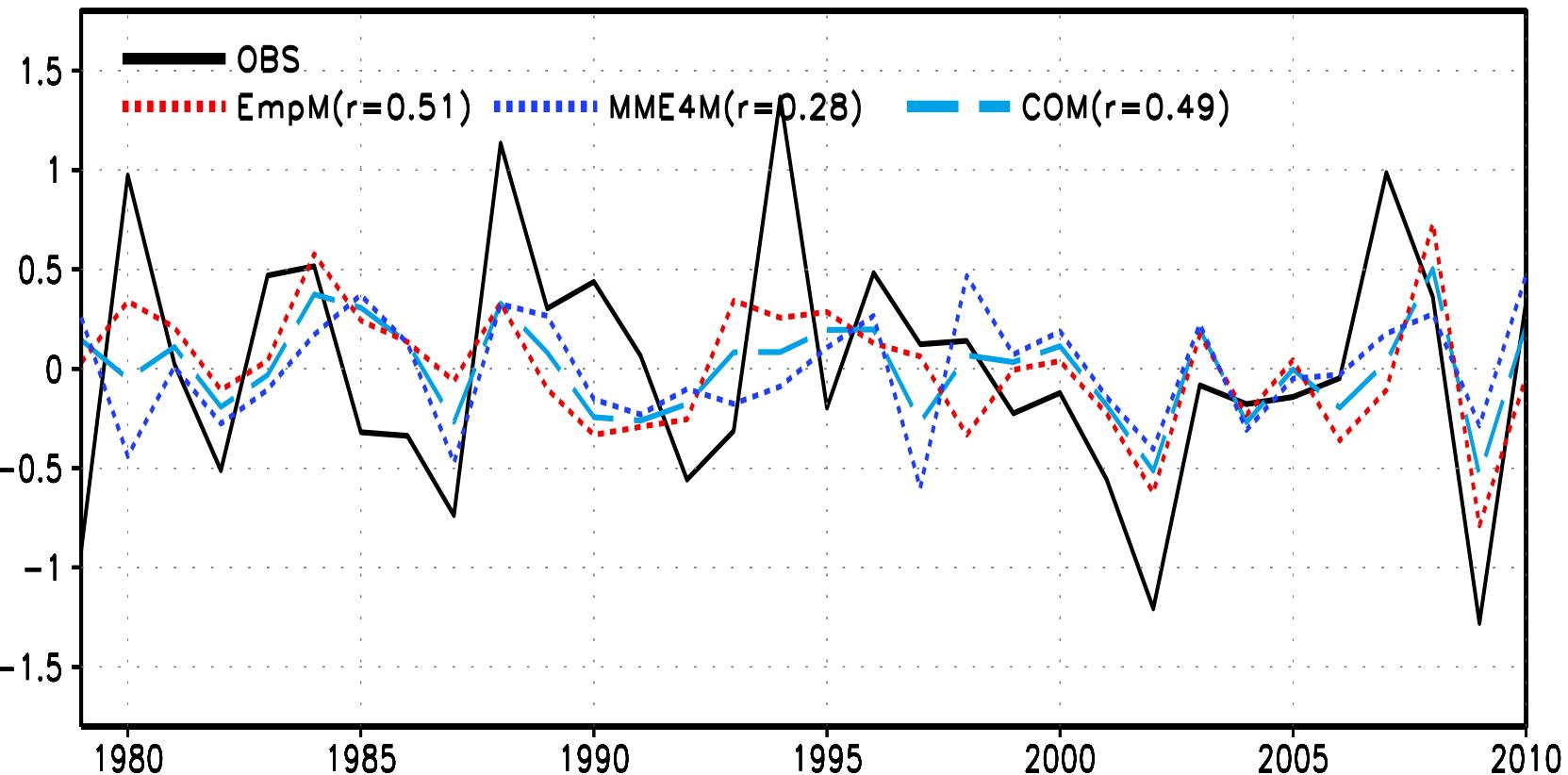
The dashed (solid) contour represents 12 % (25%) that are corresponding to the TCC of 0.35 (0.5).

PCC skill as function of time



Prediction of AIRI (1979-2010)

Indian Summer Monsoon Rainfall Anomaly



The ISM rainfall is averaged in the land region over $7.5-27.5^{\circ}\text{N}$, $70-90^{\circ}\text{E}$.

Conclusions

1. Four major modes of the ASM rainfall variability: CP-ENSO developing mode, Indo-Pacific coupled mode, IOD and global warming mode, which can explain about 47% of the total variance.
2. the four modes are, to a large extent, predictable with the physics-based empirical model and with the MME of four state-of-the-art dynamical models .
3. Dynamical and PE model are complimentary. Their combined model obtains a 32-year averaged pattern correlation skill of 0.49 with a large year-to-year variability.
4. The predictability is largely comes from the four predictable modes. PMA may provide a useful approach for estimating the seasonal potential predictability in comparison to the conventional approach based on dynamical models' ensemble simulation (MSE).

Concept of Predictable modes

